Fabrication of aligned PVA nanofibers: A new collector technique

[1]Ashish Aphale, [1]Isaac Macwan, [2]Shrinivas Bhosale, Kapil Mahakalkar, Junjie Zhang and Prabir Patra[2,3]

[1]Department of Computer Science and Engineering, University of Bridgeport, USA

[2] Department of Biomedical Engineering, University of Bridgeport, USA

[3]Department of Mechanical Engineering, University of Bridgeport, USA

Abstract

We report a laboratory developed efficient metal rotating collector design in electrospinning that aligns majority of the polyvinyl alcohol nanofibers with or without carbon nanotube inclusions. The average diameter of PVA and PVA-CNT composite nanofibers fabricated is 200 nm. A comparison of fiber diameter distribution and alignment has been established in case of static and laboratory designed rotating disc collector. Raman analysis suggests the presence of carbon nanotubes in the electrospun web. AFM suggests the thinness of the fibrous filaments and SEM shows the structural morphology of the fibers.

Introduction

Medical and healthcare textile are a rapidly growing part of the textile industry. These textiles have been engineered to have particular properties like good strength, flexibility and sometimes moisture and air permeability for medical and surgical applications. Recently electrospun nanofibers have attracted a great deal of attention for the use in medical and healthcare textile.

To the best of our knowledge, six techniques have been proposed so far to produce align nanofibers, they are rotating drum collector design, an auxiliary electrode and electrical field technique, a spinning wheel with a sharp edge technique, a frame collector technique, a multiple field technique and dual vertical wire technique. Here we present a new technique, "axially rotating collector technique" with new design of collector to fabricate aligned nanofibers that are deposited coaxially about the axis of rotating disc (collector). Previous work is also done to produce nanofibers containing CNTs. We used Poly (vinyl Alcohol) and composite PVA + CNTs polymer solution to test our technique. Using above mentioned solutions we compare the fibers that are electrospun on the stationary collector and rotating collector respectively.

Experimental Details

For the fabrication of polymer nanofibers we use electrospinning setup which has a dual syringe pump (KDS 200 series, KDS scientific, Inc.) and a high voltage electric power supply (Model ES30P, Gamma High Voltage Research, Inc.).

The PVA polymer solution is prepared and is placed in the syringe pump. We used a 10 ml volume, 12.6 mm diameter syringe to pump the PVA solution. The grounded zinc plate is used as a collector to collect the nanofibers.

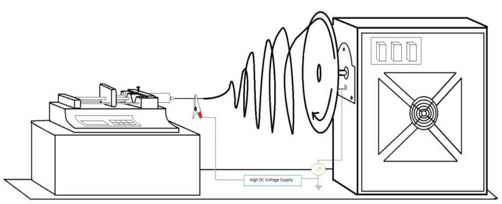


Fig2. New collector design: Rotating disc collector

As shown in Figure 1 electrospinning setup has a dual syringe pump, 0-30Kv DC high voltage electric power supply and a collector. The needle attached to the syringe is connected to a positive electrode and the collector is grounded. We apply a high voltage as high as 15 KV in order to produce the nanofibers. The PVA solution was prepared in water at a concentration of 10 % w/v. A weighted amount of PVA powder (Sigma Aldrich, Inc.) was dissolved in the water at 90°C, under slight steering for 2 hours until the we get crystal clear solution. A fixed electrical potential of 15 KV was applied over a fixed distance of 10 cm (approximately 1Kv over 1cm) at a rate of 1.5ml/ hr. We dispersed CNT in 15 % PVA solution under strong sonication for 1 hr. Here we applied a fixed voltage of 15kV over a fixed distance of 10 cm.

Results and Discussion

Above are the images taken 2 hrs after the electrospinning of nanofibers. These nanofibers were collected on the aluminum plate. Fig 3 (a, b) shows the PVA fibers made from 10 % PVA, 15 cm distance and 20 kV. Fig 3 (a) shows the image area with 500 nm magnification. Here we observe that the fibers are little less uniform in the diameter throughout the length. But the 10 um (Fig 3 (b)) magnification image shows us that there are few beads formation in nanofibers. In this the average diameter of the fibers is around 60 to 160 nm in diameter. Fig 4 (a,b) shows the nanofibers made from 10% PVA solution, 20 cm of distance and 15 kV. Fig 4 (a) shows the SEM image of 10um of magnification. Here we observe that the majority of fibers are uniform and aligned in one direction and the diameter and the average diameter is 200 nm. Here we observe that no beads formation and overall the fibers are of uniform diameter throughout the length.

Conclusion

We are demonstrating a fabrication technique for the formation of polymer nanofibers with alignment. We designed a new custom made laboratory collector design " rotating disc collector". We have clearly shown the SEM characterization to see the fibers at nm level, FTIR spectroscopy and Raman characterization. Our future scope of this project would be to test these fibers for mechanical strength under tension and shear. And also to test the electrical properties of PVA-CNT nanofibers.

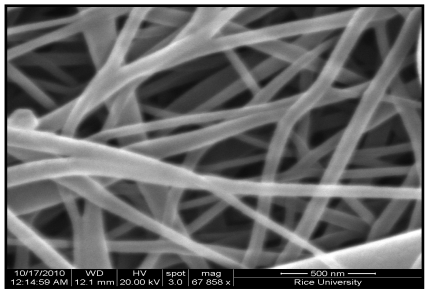


Fig. 3 (a)

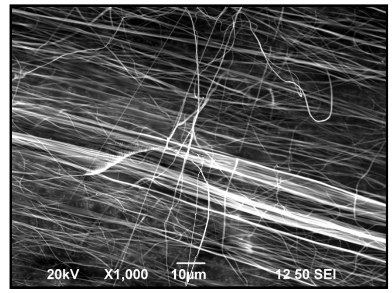


Fig. 4(a)

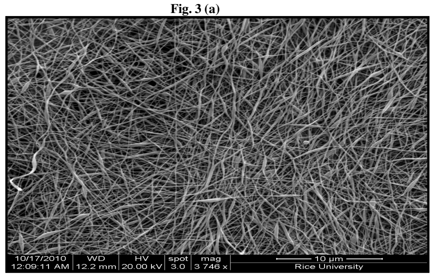


Fig. 3 (b)

Fig 3. Scanning Electron Microscope (SEM) image of 10 % PVA at 20Kv and at a distance of 15 cm on Stationary collector. Fig (a) 500 nm , Fig (b) 10 um

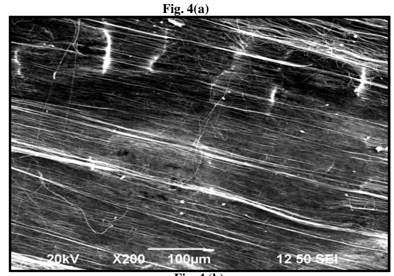
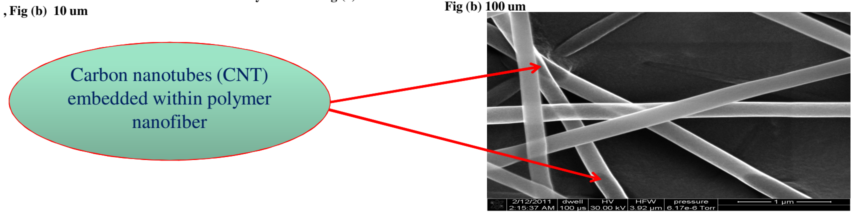


Fig. 4 (b)

Fig 4. Scanning Electron Microscope (SEM)image of 105% PVA at 15Kv and at a distance of 10 cm. on Rotating collector Fig (a) 10 um, Fig (b) 100 um



FTIR spectroscopy characterization

We performed the Fourier Transform Infrared spectroscopy to characterize the presence of PVA and to find their chemical bonding. From the literature previously published we confirm the O-H stretching from 3100 to 3600 cm^{-1} due to the strong hydrogen bond. The C-H alkyl stretching band can be observed at 2850-2950 cm-1. The absorption peaks at approximately 1710cm-1 may be attributed to C = O and peaks at 1090-1150 cm-1 to C-O.

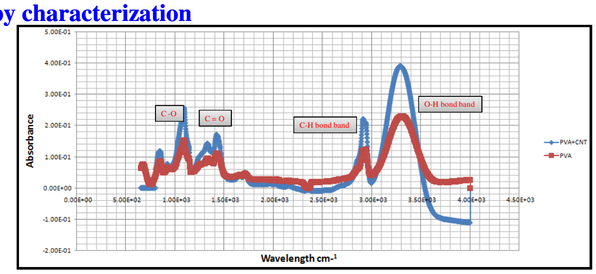
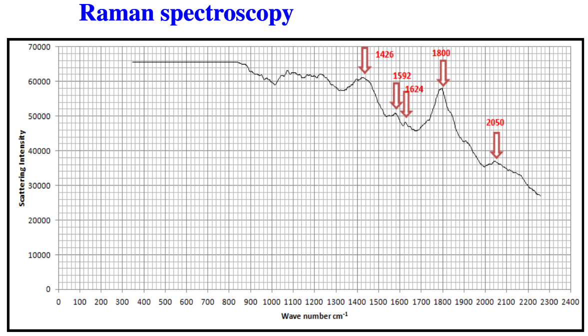


Fig 5. FTIR spectra of PVA

Raman spectroscopy

We used Raman spectroscopy to characterize the presence of CNT which is embedded in the PVA nanostructure. Raman spectra were obtained using 210nm excitation wavelength. For the PVA-CNT nanofibers sample, the *G*- peak is observed at 1592 cm^{-1}. Also the D' band at 1624 cm^{-1} was observed which is to be directly affected by the disorder in nanotubes. This band can be barely observed in the pristine CNT but is clearly visible after functionalization, indicating an increase in the defects along the tube body.



Atomic Force Microscopy AFM

The height of these nanofibers are investigated using AFM. The image in Fig.8 suggest that the height of these nanofibers is about 1.3 um. From the attached supplementary video, we can observe that the such a thin fibers are relatively lighter than the weight of air and hence when left in the air they fly for a very long time in laboratory environment. Suggesting the buoyancy force of fibers is greater than the overall weight